

[54] **HYDRAULIC CONTROL SYSTEM FOR FOUR-WHEEL DRIVE TRANSFER MECHANISM FOR VEHICLES**

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[51] Int. Cl.<sup>3</sup> ..... B60K 17/34

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[58] Field of Search ..... 180/247, 250; 74/785, 74/740, 752 A, 867, 868, 869

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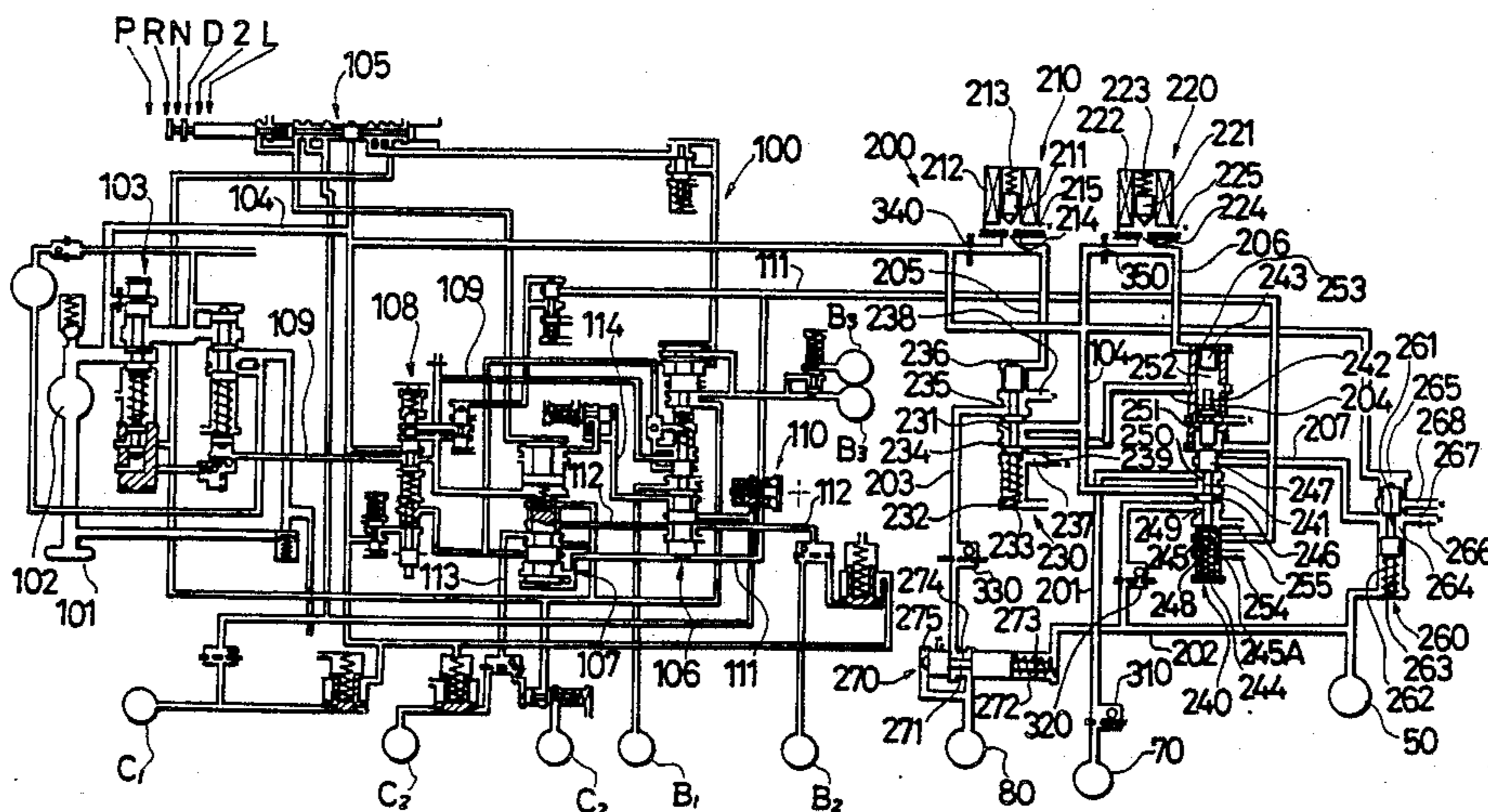
Attorney, Agent, or Firm—Blum Kaplan Friedman Silberman and Beran

[57] ABSTRACT

A hydraulic control system for a four-wheel drive

transfer mechanism for vehicles, including an automatic transmission, a transfer mechanism having a two-wheel drive direct-coupling gear (H<sub>2</sub>), a four-wheel drive direct-coupling gear (H<sub>4</sub>) and a reduced-speed four-wheel drive gear (L<sub>4</sub>) and a hydraulic control circuit for controlling the transmission and the transfer mechanism. The transfer mechanism includes a reduction gear mechanism, a first output shaft, a second output shaft connected to the first output shaft by means of a linkage, a four-wheel drive clutch for detachably connecting or disconnecting the first and second output shafts, direct-coupling clutch for connecting or disconnecting the input shaft of the reduction gear mechanism and the first output shaft and a reduced-speed drive brake for shifting the reduction gear mechanism into the reduced-speed range. The hydraulic control circuit includes a down-shift timing valve adapted to be operated by the line pressure of the hydraulic control circuit to distribute the pressurized fluid to the respective servomotors of the direct-coupling clutch and the reduced-speed drive brake so as to make the reduced-speed drive brake start engaging before the direct-coupling clutch is disengaged when the line pressure is lower than a predetermined level and to engage the reduced-speed drive brake after the direct-coupling clutch has been disengaged when the line pressure is higher than the predetermined level.

5 Claims, 8 Drawing Figures



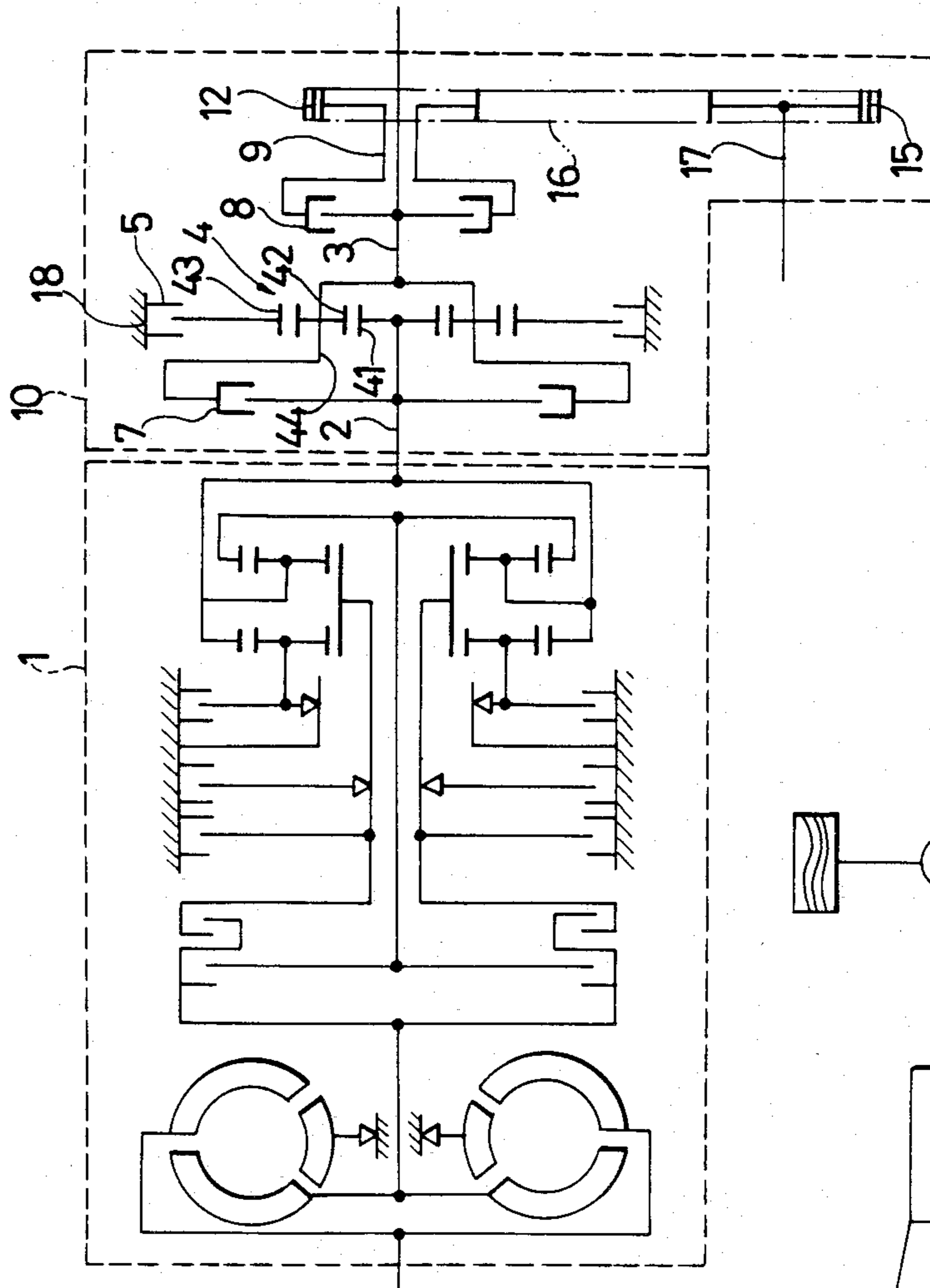


FIG. 1

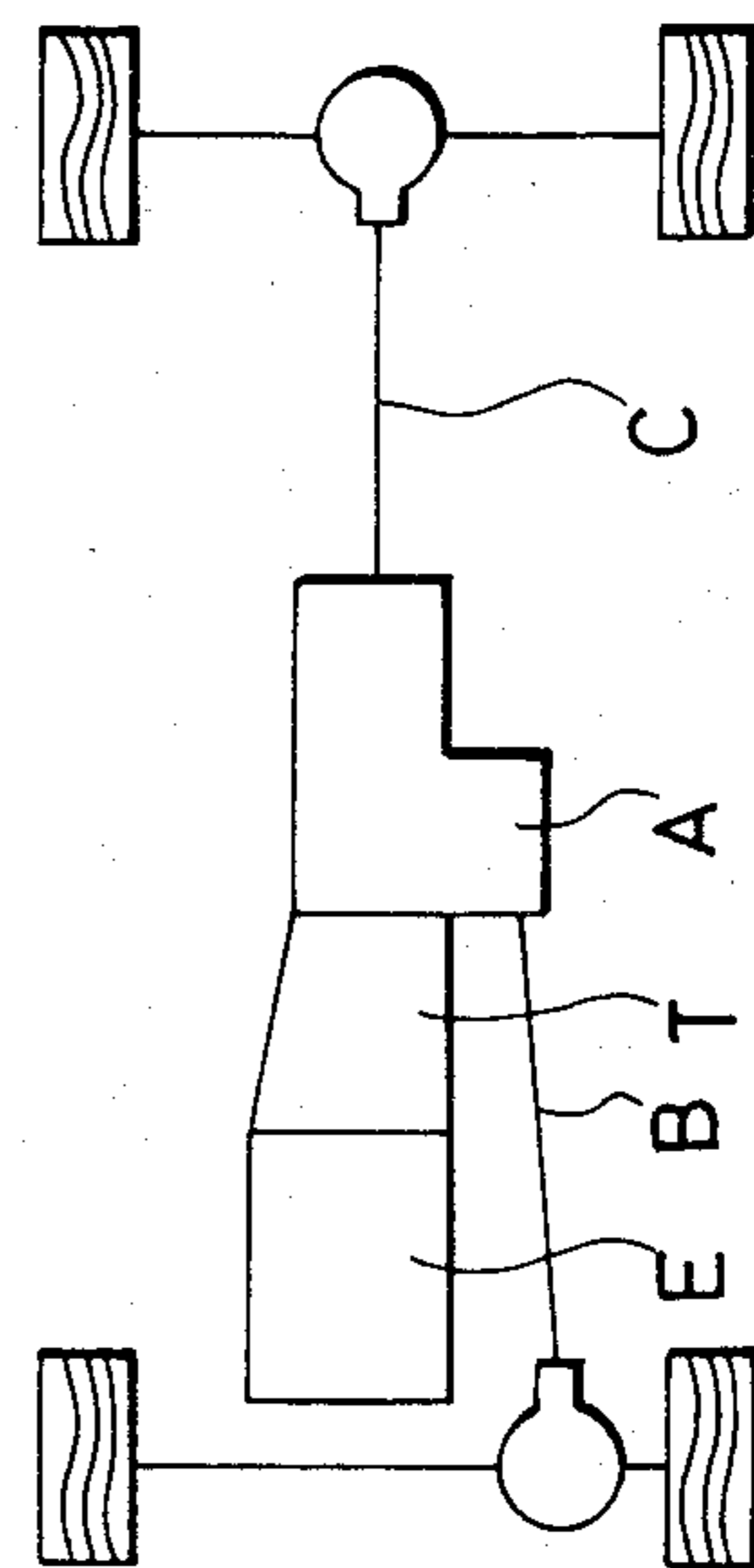


FIG. 3

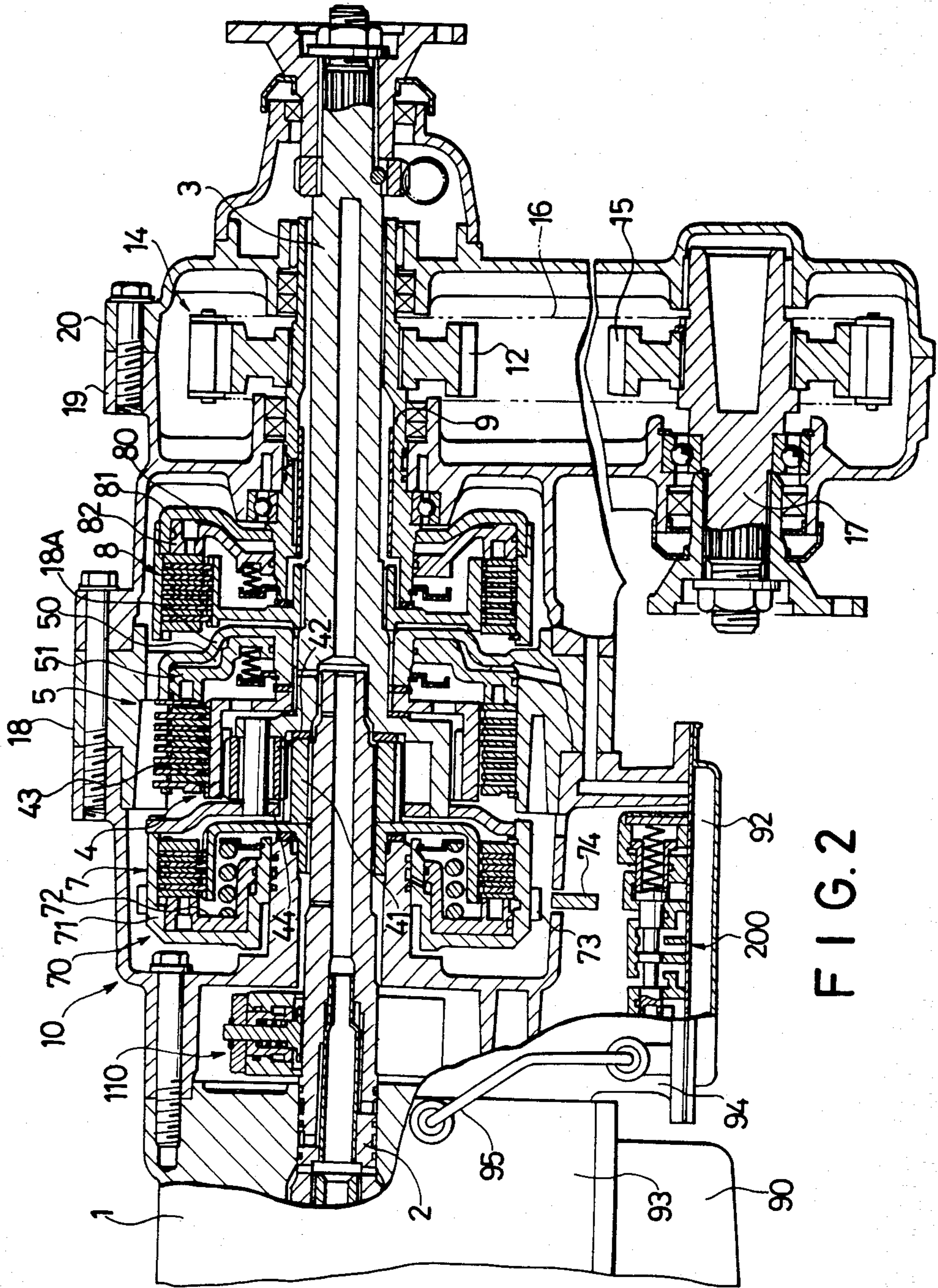


FIG. 2



FIG. 5

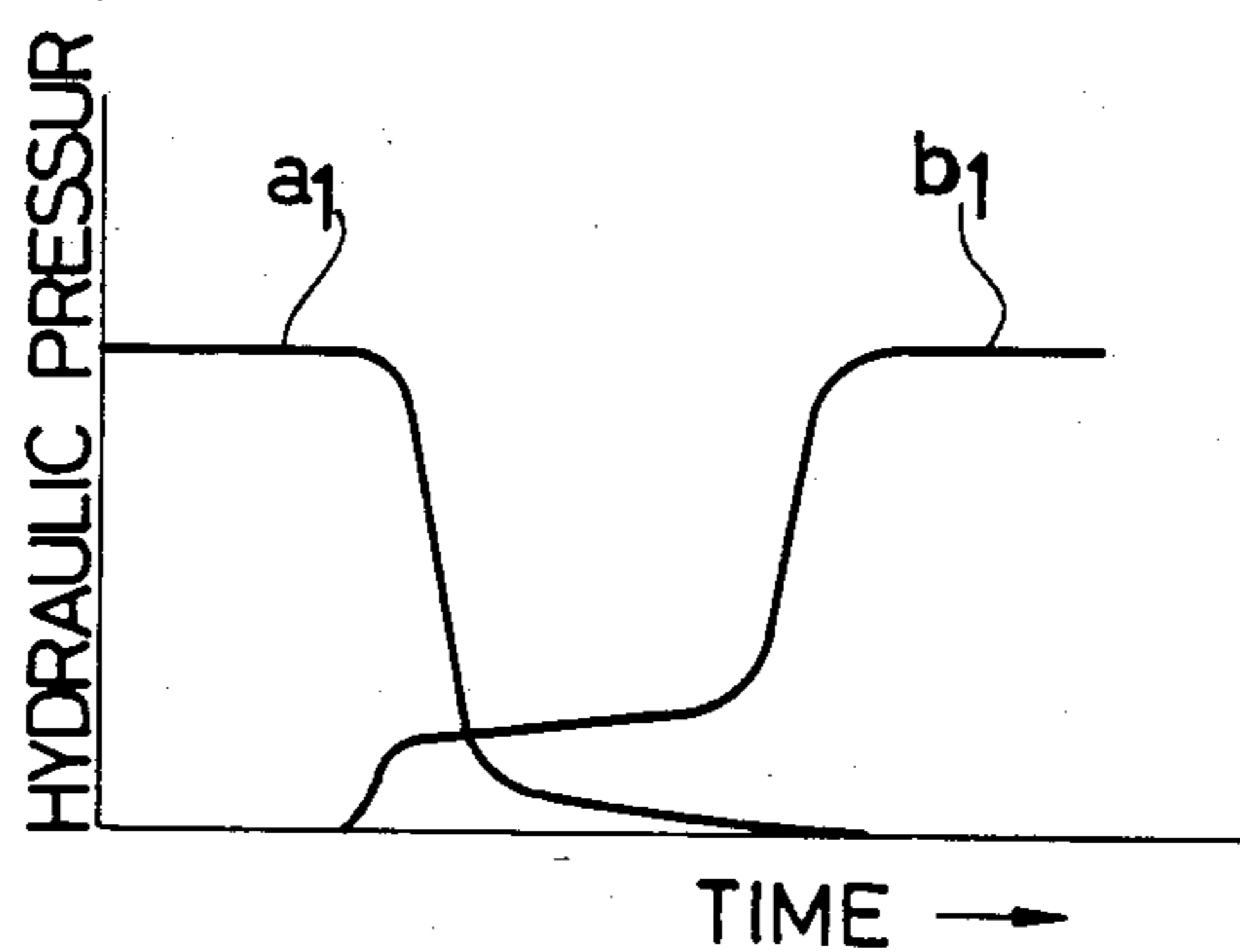


FIG. 6

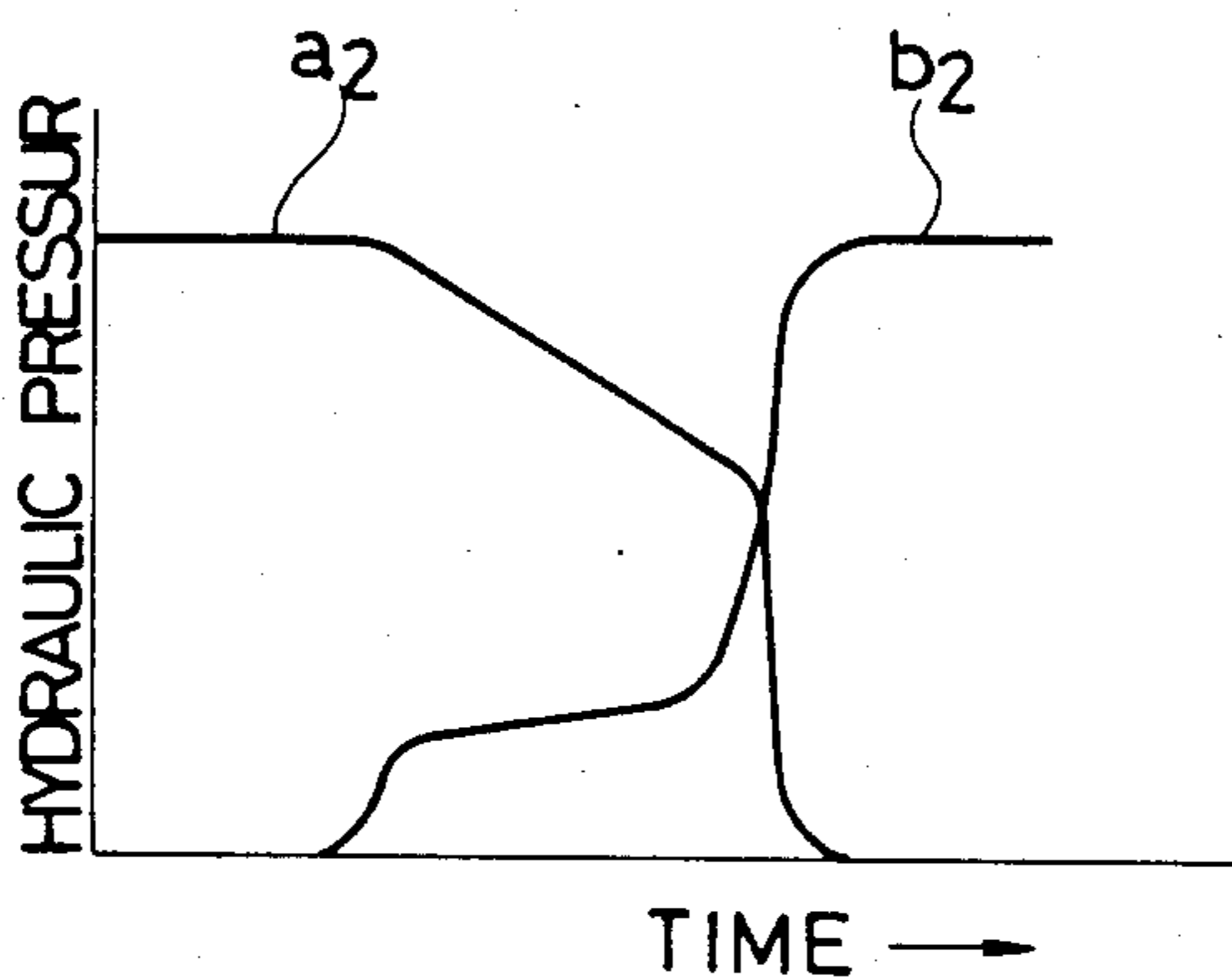


FIG. 7

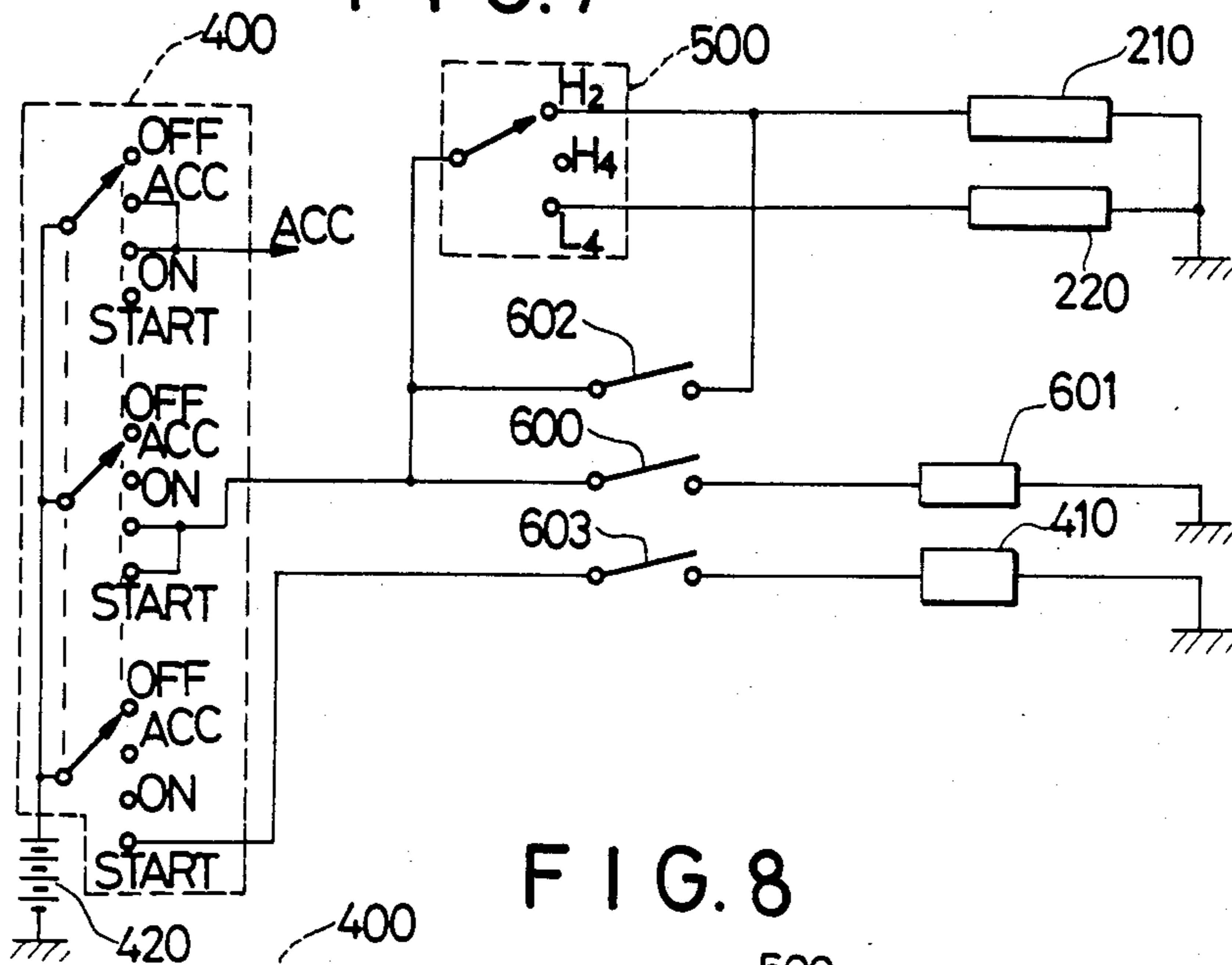
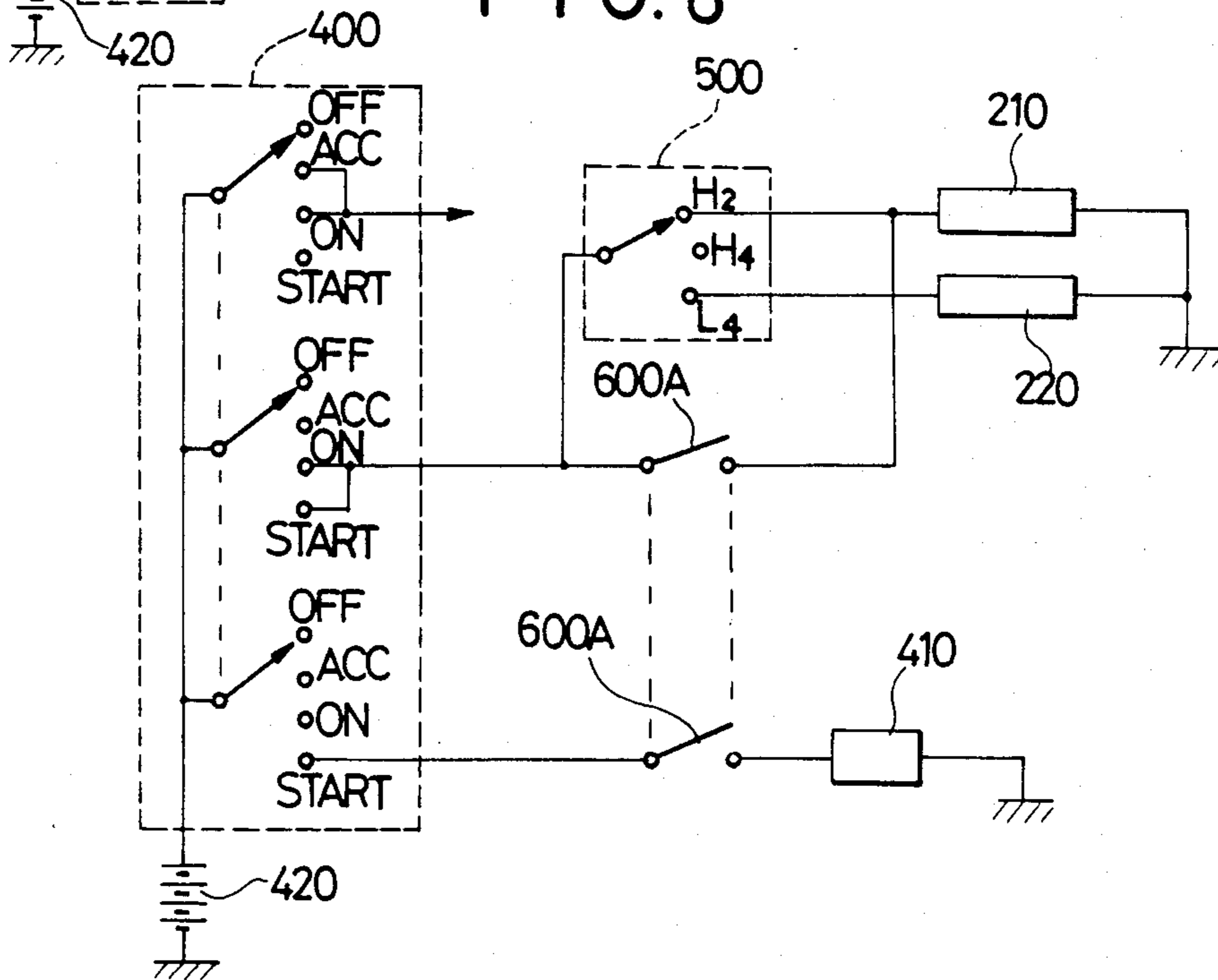


FIG. 8



## HYDRAULIC CONTROL SYSTEM FOR FOUR-WHEEL DRIVE TRANSFER MECHANISM FOR VEHICLES

### BACKGROUND OF THE INVENTION

This invention relates to a hydraulic control system for the four-wheel drive transfer mechanism connected to an automatic transmission for changing the four-wheel drive transfer mechanism between two ranges, i.e. a direct-coupling range (high-speed range) and a reduced-speed drive range (low-speed range) as well as between two-wheel drive and four-wheel drive ranges.

Generally, a transfer mechanism for four-wheel driving is changeable between two-wheel drive direct coupling range (referred to as "H<sub>2</sub>" hereinafter), four-wheel drive direct coupling range (referred to as "H<sub>4</sub>" hereinafter) and reduced speed four-wheel drive range (referred to as "L<sub>4</sub>" hereinafter). In a four-wheel drive transfer mechanism directly connected to an automatic transmission, wet multiple disk clutches and wet multiple disk brakes, which are controlled hydraulically, are employed as frictional engagement means which is controlled to engage and disengage to attain the H<sub>2</sub>, H<sub>4</sub> or L<sub>4</sub>. The hydraulic control system for controlling the changing operation is operated by the control oil pressure of the automatic transmission.

Changing between the direct coupling range and the reduced speed range in the four-wheel drive transfer mechanism is carried out by changing supply of the hydraulic fluid between the respective hydraulic mechanisms of the direct-coupling frictional engagement device and the reduced speed drive frictional engagement device, by means of an inhibitor valve (high-low selector valve). The timing of changing between the direct coupling range (high-speed range) and the reduced speed range (low-speed range), particularly the timing of shifting down from the high-speed range to the low-speed range, is a significant factor affecting generation of shocks in changing speed and the running performance of the vehicle.

For example, in changing the transfer mechanism from H<sub>4</sub> to L<sub>4</sub> while a four-wheel drive vehicle is running up a steep slope in H<sub>4</sub> to cope with a requirement for a greater driving force, the transfer mechanism is set temporarily in the neutral mode during the changing operation when the reduced-speed drive frictional engagement device is engaged after the direct-coupling frictional engagement device has been disengaged and the vehicle thereby may unexpectedly run down the slope, which is dangerous. Accordingly, an overlapping changing operation is more preferable.

However, in changing the transfer mechanism from H<sub>4</sub> to L<sub>4</sub> while the vehicle is running along a level road at a low speed, the overlapping changing operation will cause an increased changing shock, which is undesirable. In this case, therefore, it is preferable to engage the reduced-speed drive frictional engagement device after the direct-coupling frictional engagement device has been disengaged.

However, the aforementioned inhibitor valve (high-low selector valve) alone can not set a change speed timing corresponding to the running state as described hereinbefore.

### SUMMARY OF THE INVENTION

Generally speaking, in accordance with the present invention, a hydraulic control system, especially a hy-

draulic control system suitable for smoothly changing the transfer mechanism from the direct-coupling range to the reduced-speed drive range corresponding to the running speed of the vehicle, is provided. The present invention relates to a hydraulic control system for a four-wheel drive transfer mechanism for vehicles, having a two-wheel direct drive gear, four-wheel direct drive gear and reduced-speed four wheel drive gear.

The hydraulic control system includes frictional engagement means for the direct drive gear of the transfer mechanism (hereinafter referred to as direct-coupling frictional engagement means), frictional engagement means for the reduced-speed four-wheel drive gear (hereinafter referred to as reduced-speed drive frictional engagement means), a frictional engagement means for four-wheel drive gear (hereinafter referred to as four-wheel drive frictional engagement means) and means to engage the reduced-speed frictional engagement means after the direct-coupling frictional engagement means has been disengaged when the throttle opening of the internal combustion engine of the vehicle is below a predetermined value.

More particularly, the four-wheel drive transfer mechanism includes a reduction gear mechanism having an input shaft connected to the output end of an automatic transmission, a first output shaft connected to the output end of the reduction gear mechanism, a second output shaft rotatably connected or disconnected to the first output shaft through a linkage and the four-wheel drive frictional engagement means, the direct-coupling frictional engagement means for directly engaging and disengaging the input shaft of the reduction gear mechanism and the first output shaft and the reduced-speed drive frictional engagement means for setting the reduction gear mechanism in the mode of a high reduction ratio.

The hydraulic control system includes first control valve means for supplying pressurized fluid to and draining pressurized fluid from the servomotor of the four-wheel drive frictional engagement means and second control valve means which operates selectively to supply pressurized fluid either to the servomotor of the direct-coupling frictional engagement means or to the servomotor of the reduced-speed drive frictional engagement means and to drain the other. The hydraulic control system includes further third control valve means. The third control valve means is controlled according to a signal having a component commensurate with the opening of the carburetor throttle of the internal combustion engine to regulate the sectional area of a drain passage for the servomotor of the direct-coupling frictional engagement means.

Accordingly, it is an object of the present invention to provide a hydraulic control system for a four-wheel drive transfer mechanism for vehicles, which hydraulic control system is operative to establish the reduced-speed drive range of the transfer mechanism smoothly when the transfer mechanism is shifted down manually from the direct-coupling range to the reduced-speed drive range irrespectively of the running speed of the vehicle.

A further object of the present invention is to provide a hydraulic control system for a four-wheel drive transfer mechanism which is connected to the rear end of an automatic transmission and capable of being changed between a two-wheel drive direct-coupling range, four-wheel drive direct-coupling range and reduced-speed

four-wheel drive range by means of the direct-coupling frictional engagement means, reduced-speed drive frictional engagement means and four-wheel drive frictional engagement means, in which the hydraulic control system includes means to make disengaging operation of the direct-coupling frictional engagement means and engaging operation of the reduced-speed drive frictional engagement means overlap with each other when the throttle opening of the internal combustion engine of the vehicle is above a predetermined value and to engage the reduced-speed drive frictional engagement means after the direct-coupling frictional engagement means has been disengaged when the throttle opening of the internal combustion engine of the vehicle is below a predetermined value in shifting down from the direct-coupling range to the reduced-speed drive range and thus capable of appropriately controlling the timing of the down-shift operation of the transfer mechanism according to the running state of the vehicle.

The hydraulic control system of the present invention for a four-wheel drive transfer mechanism is characterized in provision of means which is capable of making disengaging operation of the direct-coupling frictional engagement means and engaging operation of the reduced-speed drive frictional engagement means overlap with each other when the throttle opening of the internal combustion engine of the vehicle is above a predetermined value and to engage the reduced-speed drive frictional engagement means after the direct-coupling frictional engagement means has been disengaged when the throttle opening of the internal combustion engine of the vehicle is below a predetermined value in shifting down the four-wheel drive transfer mechanism from the direct-coupling range to the reduced-speed drive range which mechanism is connected to the rear end of an automatic transmission and capable of being changed between a two-wheel drive direct-coupling range, four-wheel drive direct-coupling range and reduced-speed four-wheel drive range by means of the respective frictional engagement means for direct-coupling, reduced-speed drive and four-wheel drive.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic illustration of a power transmitting system according to a preferred embodiment of the present invention, in which a transfer mechanism of the present invention is connected to the output end of a known automatic transmission,

FIG. 2 is a detail sectional view of the power transmitting system of FIG. 1,

FIG. 3 is a schematic illustration of the power transmitting system of a vehicle,

FIG. 4 is the circuit diagram of a hydraulic control system for a four-wheel drive transfer mechanism according to the present invention as applied to an auto-

matic transmission of three forward ranges and one reverse range,

FIG. 5 is a graph showing the variation of hydraulic pressure in the hydraulic servomotor 50 and 70 with time during down-shift operation when the line pressure is below a predetermined level,

FIG. 6 is a graph showing the variation of hydraulic pressure in the hydraulic servomotor 50 and 70 with time during down-shift operation when the line pressure is above the predetermined level,

FIG. 7 is a circuit diagram of an electric control circuit for controlling the hydraulic control system, and

FIG. 8 is a circuit diagram of another electric control circuit controlling the hydraulic control system.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

Hereafter, the invention is illustrated more particularly by way of the preferred embodiments shown in the drawings, in which generally indicated at 1 is a transmission gear assembly of the automatic transmission and at 10 a torque transfer mechanism which is connected to the output end (the right end in FIG. 2) of the transmission gear assembly through a shaft 2 which serves as an output shaft of the transmission gear assembly 1 and at the same time as an input shaft of the torque transfer mechanism 10. Denoted at 3 is a first output shaft of the transfer mechanism 10, which is located behind the input shaft 2 (on the right side in FIG. 2) in series therewith, at 110 a governor valve which is securely mounted on the input shaft 2, and at 4 a planetary gear set including a sun gear 41 which is secured by a spline on a rear portion of the input shaft 2, planetary pinions 42 in meshing engagement with the sun gear 41, a ring gear 43 in meshing engagement with the planetary pinions 42, and a carrier 44 rotatably retaining the planetary pinions 42 and coupled with the fore end of the first output shaft 3 of the transfer mechanism. Designated at 5 is a friction brake for engaging and disengaging the ring gear 43 with a transfer case 94, and at 50 a hydraulic servomotor for the brake 5, which is constituted by a cylinder 18A formed in the transfer case 18 and a piston 51 slidably fitted in the cylinder 18A. The sun gear 41 and carrier 44 are coupled and uncoupled by a hydraulic servomotor 7 which is at one end of the planetary gear set 4 on the side of the transmission gear assembly and which is constituted by a cylinder 71 connected to the carrier 44 and a piston 72 fitted in the cylinder 71. Denoted at 8 is a friction clutch for engaging and disengaging the first output shaft 3 and a sleeve 9 connected to one sprocket wheel 12 of a link mechanism which drives the other output shaft of the transfer mechanism as will be described hereinafter. The reference numeral 80 indicates a hydraulic servomotor constituted by a cylinder 81 welded to the sleeve 9, which is rotatably retained in the transfer cases 19 and 20, and a piston 82 slidably fitted in the cylinder 81. Further designated at 17 is the second output shaft of the transfer mechanism, and at 14 a link mechanism which is constituted by the sprocket wheel 12 secured by a spline to the sleeve 9, a sprocket wheel 15 secured by a spline to the second output shaft 17, and a chain 16 lapped between and around the two sprocket wheels.

Provided around the circumference of the hydraulic cylinder 71 of the friction clutch 7 is a parking gear 73 with which a stopper 74 is engaged when the shift lever of the automatic transmission is put in the parking position, thereby fixing the first output shaft 3.



Indicated at 90 is an oil pan of the automatic transmission, at 200 a hydraulic control system which controls the oil pressure flows to and from the hydraulic servomotors 70, 80 and 50 of the clutches 7 and 8 and the brake 5 of the four-wheel transfer mechanism 10, and at 92 an oil pan of the hydraulic control system 200. The oil pressure to be supplied to the hydraulic servomotors of the clutches 7 and 8 and brake 5 is fed through a pipe 94 which is supported on a case 93 of the automatic transmission and a transfer case 94 and through the hydraulic control system 200 from the oil pan 90.

As indicated at A in FIG. 3, the transfer mechanism is assembled with an automatic transmission T which is connected to an internal combustion engine E of a motor vehicle, with its first output shaft 3 connected to a rear wheel propeller shaft and the other or the second output shaft 17 to a front wheel propeller shaft B. In a normal cruising operation, the line pressure which is supplied to the hydraulic control circuit of the automatic transmission is fed to the hydraulic servomotor 70 to engage the clutch 7, while the hydraulic servomotors 50 and 80 are drained to hold the brake 5 and clutch 8 in released state. Consequently, the sun gear 41 and carrier 44 of the planetary gear set 4 are coupled to transmit power to the first output shaft 3 from the input shaft 2 in a reduction ratio of 1 for operation in rear two-wheel drive. In this instance, the power from the input shaft 2 is transmitted to the first output shaft 3 from the carrier 44 through clutch 7, by-passing the gears 41 to 43 which therefore receive no load on their tooth faces and can have a prolonged service life. If it is desired to switch the mode of operation from two-wheel drive to four-wheel drive, a selector lever or switch which is provided in the driver's cabin is manipulated for manual shift, actuating the hydraulic control system 200 of the transfer mechanism whereupon the line pressure is supplied gradually to the hydraulic servomotor 80 to engage the clutch 8 smoothly. As a result, the first output shaft 3 is connected with the sleeve 9 to transmit the power also to the front wheels through the link mechanism 14, second output shaft 17 and propeller shaft B to operate the vehicle in the four-wheel drive mode transmitting the power of the input shaft 2 in a reduction ratio of 1 to the first output shaft 3 which drives the front wheels as well as to the second output shaft 17 which drives the rear wheels. If a greater output torque is required for hill climbing or other reasons during operation in the four-wheel drive mode, the oil pressure to the hydraulic servomotors actuates an inhibitor valve 240, a downshift timing valve 260 and a check valve 320 to supply the line pressure gradually to the hydraulic servomotor 50 while draining the oil pressure of the hydraulic servomotor 70, thereby gradually engaging the brake 5 and at the same time releasing the clutch 7 smoothly. As a result, the sun gear 41 and carrier 44 are released and the ring gear 43 is held stationary, so that the rotation of the input shaft 2 is transmitted to the first and second output shafts 2 and 17 after reduction through the sun gear 31, planetary pinions 42 and carrier 44 to establish a four-wheel drive operation of a greater torque. Table 1 below shows the positions of the manual shift of the transfer mechanism in relation with the engaged or released states of the brake 5 and clutches 7 and 8 and the mode of operation.

TABLE 1

Manual Shift	Mode of Operation	Frictional Engagement Means			Reduction ratio
		5	7	8	
H <sub>2</sub> range	Two-wheel drive	X	O	X	1
H <sub>4</sub> range	Four-wheel drive direct-coupling	X	O	O	1
L <sub>4</sub> range	Four-wheel drive direct-coupling	X	O	O	1
	Reduced-speed four-wheel drive	O	X	O	$\frac{1+\lambda}{\lambda} = 3.0$

In Table 1, the marks "O" and "X" indicate the engaged and released states of the frictional engagement means, respectively. The symbol " $\lambda$ " in the reduction ratio represents the ratio in the number of teeth of the sun gear 41 to the ring gear 43, and is regarded as 0.5 in the example shown in Table 1.

Referring now to FIG. 4, the hydraulic control system for four-wheel drive torque transfer mechanism according to the present invention is hereafter described more particularly by way of a case where it is connected to an automatic transmission with three forward speed positions and one reverse position.

In the figure, generally designated by the reference numeral 100 is an example of known automatic transmission with three forward speed gears and one reverse gear, in which the oil taken up from an oil sump 101 by an oil pump 102 is regulated into a predetermined pressure (line pressure) at the pump output by a regulator valve 103 and delivered to a conduit 104. The oil pressure inputted to the conduit 104 is fed to a 1-2 shift valve 106 and a 2-3 shift valve 107 through a manual selector valve 105. Indicated at 108 is a throttle valve which generates an oil pressure (throttle pressure) in a conduit 109 commensurate with the degree of throttle opening. Indicated at 110 is a governor valve which generates an oil pressure (governor pressure) commensurate with the vehicle speed in a conduit 111.

The 1-2 shift valve 106 and 2-3 shift valve 107 open and close the conduits 112 to 114 according to the level of the throttle and governor pressures supplied through the conduit 109 and 111, thereby controlling the supply and discharge of oil pressure to and from the hydraulic servomotors C<sub>1</sub>, C<sub>2</sub> and B<sub>1</sub> to B<sub>3</sub> of the clutches and brakes.

In the particular embodiment shown, the oil pressure is supplied to the hydraulic servomotor C<sub>1</sub> in the forward 1st speed range, to the hydraulic servomotors C<sub>1</sub> and B<sub>2</sub> in the forward 2nd speed range, to hydraulic servomotors C<sub>1</sub>, C<sub>2</sub> and B<sub>2</sub> in the forward 3rd speed range, and to the hydraulic servomotors C<sub>2</sub> and B<sub>3</sub> in the reverse range.

The hydraulic control system 200 for the four-wheel drive torque transfer mechanism includes a first solenoid valve 210, a second solenoid valve 220, a change-over valve 230, an inhibitor valve 240, downshift timing valve 260, a first conduit 201 communicating with the hydraulic servomotor 70 for the direct-coupling frictional engagement means or the multiple disc clutch 7, a second conduit 202 communicating with the hydraulic servomotor 50 for the reduced-speed drive frictional engagement means or the multiple disc brake 5, a third conduit 203 communicating with the hydraulic servomotor 80 for the four-wheel drive frictional engagement means or the multiple disc clutch 8, a modulator valve 270 provided in the third conduit 203, a fourth

conduit 204 communicating the change-over valve 230 with a predetermined oil chamber of the inhibitor valve 240, check valves 310, 320 and 330 provided in the first to third conduits, respectively, and conduit 205 of the first solenoid pressure and a conduit 206 of the second solenoid pressure communicating with conduit 104 through orifices 340 and 350, respectively.

The first and second solenoid valves 210 and 220 consist of a moving core 211 or 221, a solenoid 212 or 222, a spring 213 or 223, an opening 214 or 224 and a drain port 215 or 225, respectively. Upon energizing the solenoids 212 and 222, the moving cores 211 and 221 are moved in upper positions shown in the drawing to uncover the openings 214 and 224 to drain through the drain ports 215 and 225 the oil pressure in the conduits 205 and 206 which are partitioned off from conduit 104 by the orifices 340 and 350, respectively. When the solenoids 212 and 222 are in de-energized state, the moving cores 211 and 222 are displaced downward from the upper positions of FIG. 4 into the respective lower positions by the action of the springs 213 and 223 to close the openings 214 and 224 to generate a solenoid pressure of high level (line pressure) in the conduits 205 and 206.

As shown in FIG. 4, the inhibitor valve 240 is provided with three spools 241, 242 and 243 which are designated as first, second and third spools from the lower ones. The first spool 241 is provided with a spring-loaded sleeve-like land 245 at its lower end in addition to two lands 246 and 247, and formed with a lower oil chamber 248, first and second intermediate oil chambers 249 and 250 defined between the sleeve-like land 245 and the lands 246 and 247, an oil chamber 251 defined between the first and second spools 241 and 242, an oil chamber 252 defined between the second and third spools 242 and 243, and an upper oil chamber 253. When the first spool 241 of the inhibitor valve 240 is located in an upper position, above the illustrated position in FIG. 4, the lower oil chamber 248 is communicated with the governor pressure conduit 111 through an oil port 245A in the sleeve-like land 245, the first intermediate oil chamber 249 communicates the line pressure conduit 104 with the second conduit 202, and the second intermediate oil chamber 250 communicates the first conduit 201 with the drain port 256 or a fifth conduit 207. On the other hand, when the first spool 241 is held in the lower position shown, the lower oil chamber 248 communicates with the drain port 254 through the oil port 245A in the sleeve-like land 245, the first intermediate oil chamber 249 communicates the second conduit 202 with the drain port 255, and the second intermediate oil chamber 250 communicates the line pressure conduit 104 with the first conduit 201. The oil chamber 251, oil chamber 252 and upper oil chamber 253 are constantly in communication with the governor pressure conduit 111, the fourth conduit 204 and the conduit 206, respectively.

The change-over valve 230 is loaded with a biasing spring 232 as seen in the drawing on the lower end portion of a spool 231 which is provided with three lands, defining a lower oil chamber 233, a first intermediate oil chamber 234, a second intermediate oil chamber 235 and an upper oil chamber 236 from the lower ones. If the solenoid pressure of high level is applied to the upper oil chamber 236 which is in communication with conduit 205 of the first solenoid pressure, the spool 231 is displaced downward from the illustrated position in the drawing to assume a lower position, communicat-

ing the line pressure conduit 104 with the third conduit 203 through the second intermediate oil chamber 235 to supply the line pressure to the hydraulic servomotor 80 of the clutch 8, and communicating the fourth conduit 204 with a drain port 237 provided with an orifice 239 through the first intermediate oil chamber 234 to drain the oil chamber 252 of the inhibitor valve 240. If the solenoid pressure applied to the upper chamber 236 turns to low level, the spool 231 is displaced into the upper position as shown in the drawing by the action of the spring 232, communicating the line pressure conduit 104 with the fourth conduit 204 through the first intermediate oil chamber 234 to supply line pressure to the oil chamber 252 of the inhibitor valve 240, and communicating the third conduit 203 with a drain port 238 through the second intermediate chamber to drain the hydraulic servo 80.

The down-shift timing valve 260 has a spring 262 disposed in the lower part thereof, as seen in the drawing, a spool 261 having two lands and three oil chambers arranged from the bottom to upward in the drawing, a bottom oil chamber 263, middle oil chamber 264 and top oil chamber 265. In the valve 260, the bottom oil chamber 263 is always in communication with the second conduit 202 while the top oil chamber 265 is always in communication with the line pressure conduit 104. The middle oil chamber 264 communicates always with the fifth conduit 207 and a drain port 266 provided with an orifice 267 for gradual draining, and further, with a drain port 268 when the spool 261 is set at the upper position for quick draining. The spool 261 is set at the upper position when the line pressure applied to the top chamber 265 is below the predetermined level, namely, when the throttle opening is small, hence the hydraulic pressure working on the spool 261 is smaller than the counterforce of the spring 262 or when the pressure for engaging the multiple disk brake 5 is applied to the bottom oil chamber 263.

The modulator valve 270 has a spring 272 disposed on the right-hand side thereof, in the drawing, a spool 271 having two lands and three oil chambers arranged from the right to the left, a right oil chamber 273, middle oil chamber 274 and left oil chamber 275. In the valve 270, the right oil chamber 273 communicates always with the second conduit 202, the middle oil chamber 274 intersects with the third conduit 203 and the left oil chamber 275 communicates with the third conduit 203 connecting with the hydraulic servomotor 80. When the pressure for engaging the brake 5 is applied to the right oil chamber 273, the third conduit 203 is fully opened, whereas the pressure within the third conduit 203 is regulated when the pressure for engaging the brake 5 is removed.

If the range of H<sub>2</sub> or H<sub>4</sub> or L<sub>4</sub> is selected by manipulation of a manual shift (a selector switch in this particular embodiment) which is provided in the driver's cabin, the first and second solenoid valves 210 and 220 are turned on or off as shown in Table 2 by the operation of an electric control circuit which will be described hereinafter, selectively supplying the operating oil pressure from the hydraulic control system of the torque transfer mechanism to the hydraulic servomotors 50, 70 and 80 of the respective frictional engagement means to change the transfer mechanism 10 into the gear position of the selected mode (H<sub>2</sub> or H<sub>4</sub> or L<sub>4</sub>). In the above-described hydraulic circuit arrangement, if the first solenoid valve 210 is turned on, the transfer mechanism 10 is set in the

gear position of H<sub>2</sub> mode irrespective of the on- or off-state of the second solenoid valve 220.

Table 2 below shows the on- and off-states of the first and second solenoid valves 210 and 220 in relation with the selected range of manual shift and the transfer gear position, wherein the symbol "ON" and "OFF" represent the energization and de-energization of the solenoid valve, respectively.

TABLE 2

Manual valve selected range	Transfer manual shift	Solenoid valve 210	Solenoid valve 220	Gear position
D.2.L.	H <sub>2</sub> range	ON	OFF	H <sub>2</sub>
	H <sub>4</sub> range	OFF	OFF	H <sub>4</sub>
	L <sub>4</sub> range	OFF	ON	H <sub>4</sub> /L <sub>4</sub>
N.P.	H <sub>2</sub> range	ON	OFF	H <sub>2</sub>
	H <sub>4</sub> range	ON	OFF	H <sub>2</sub>
	L <sub>4</sub> range	ON	ON	H <sub>2</sub>

As clear from Table 2, upon energization of the first solenoid valve 210, the line pressure which is led from conduit 104 to conduit 205 through orifice 340 is drained through the drain port 215 to hold the spool 231 of the change-over valve 230 in the upper position shown, so that the oil pressure in the hydraulic servomotor 80 of the multiple disc clutch 8 is drained through the drain port 238 to release the clutch 8. The release of the multiple disc clutch 8 results in disconnection of the first output shaft 3 from the sleeve 9, namely, disconnection of the first output shaft 3 from the second output shaft 17, putting the transfer mechanism in the gear position of two-wheel drive mode. At the same time, the line pressure from conduit 104 is applied to the oil chamber 252 of the inhibitor valve 240 through the oil chamber 234 and the fourth conduit 204 to shift the first and second spools 241 and 242 of the inhibitor valve 240 into the respective lower positions shown, so that the line pressure of conduit 104 is fed to the hydraulic servomotor 70 through the oil chamber 250, first conduit 201 and check valve 310 to engage the multiple disc clutch 7, while the oil pressure in the hydraulic servomotor 50 is drained from the drain port 255 through the conduit 202 and oil chamber 249 to release the brake 5. As a result, the transfer mechanism 10 is held in the gear position of two-wheel drive direct-coupling range.

When the first solenoid valve 210 is in de-energized state, the line pressure of the conduit 104 is led to the conduit 205 through orifice 340, however, since the opening 214 of the first solenoid valve 210 is closed, it is admitted into the upper oil chamber 236 of the change-over valve 230, displacing the spool 231 into the lower position. Consequently, the line pressure of the conduit 104 is fed to the hydraulic servomotor 80 through the second intermediate oil chamber 235, third conduit 203 and check valve 330 to engage the multiple disc clutch 8. The engagement of the multiple disc clutch 8 connects the first output shaft 3 with the second output shaft 17 through the link mechanism to put the transfer mechanism in the gear position of four-wheel drive direct-coupling range. The communication between the fourth conduit 204 and 104 is blocked, the line pressure is not led in the oil chamber 252 of the inhibitor valve 240. Under these circumstances, if the second solenoid valve 220 is in de-energized state, the line pressure of the conduit 104 is admitted into the upper oil chamber 253 of the inhibitor valve 240 through orifice 350 and conduit 206 to shift the third spool 243 of the inhibitor valve 240 into the lower position, holding the second and first spools 242 and 241 also in the respective lower

positions. Accordingly, the line pressure is fed from the conduit 104 to the hydraulic servomotor 70 through the conduit 201 and check valve 310 to engage the multiple disc clutch 7, while the oil pressure in the hydraulic servomotor 50 is drained from the drain port 255 through the conduit 202 and oil chamber 249 to release the multiple disc brake 5, holding the transfer mechanism 10 in gear the position of H<sub>4</sub> (4-wheel drive direct-coupling) range.

If the second solenoid valve 220 is energized with the first solenoid valve 210 in de-energized state, the line pressure which is fed from the conduit 104 to conduit 206 through the orifice 350 is drained through the opening 224 and drain port 255, without being admitted into the upper oil chamber 253 of the inhibitor valve 240. Further, the first solenoid valve 210 is in de-energized state, so that no line pressure is supplied to the oil chamber 252 from the fourth conduit 204. The pressure receiving surface at the upper end of the first spool 241 of the inhibitor valve 250, which faces the oil chamber 251, has the same area as the pressure receiving surface at the lower end which faces the lower oil chamber 248. Therefore, in a case where the first spool 241 is in the lower position shown, namely, in the gear position of H<sub>4</sub> (4-wheel drive direct-coupling) range where the multiple disc clutch 7 is in engaged state and the multiple disc brake 5 is in released state, the first spool 241 is continually held in the lower position overcoming the force of the spring 244 to maintain the transfer mechanism in the gear position of H<sub>4</sub> (4-wheel drive direct-coupling) range as long as the governor pressure supplied to the oil chamber 251 from the conduit 111 is greater than a predetermined level. However, if the governor pressure drops below the predetermined value, the first spool 241 is shifted into the upper position by the action of the spring 244, so that the governor pressure from the conduit 111 is also admitted into the lower oil chamber 248 through the oil port 245A of the sleeve-like land 245, retaining the first spool 241 in the upper position irrespective of variations in the governor pressure (i.e., in vehicle speed) thereafter. With the first spool 241 held in the upper position, the line pressure in conduit 104 is fed to the hydraulic servomotor 50 through the oil chamber 249, second conduit 202 and check valve 320 to engage the multiple disc brake 5, while the oil pressure in the hydraulic servomotor 70 is drained through conduit 201, oil chamber 250 and drain port 256 or the fifth conduit 207 to release the multiple disc clutch 7. Consequently, the transfer mechanism 10 is held in the gear position of L<sub>4</sub> range (reduced-speed four-wheel drive mode).

Namely, if the second solenoid valve 220 is energized when the first solenoid valve 210 is de-energized state and the governor pressure or the vehicle speed is lower than a predetermined value, the transfer mechanism 10 is immediately changed into the gear position of L<sub>4</sub> range (reduced-speed four-wheel drive mode). However, if the second solenoid valve 220 is energized when the governor pressure or the vehicle speed is higher than the predetermined value, the transfer mechanism 10 retains the gear position of H<sub>4</sub> (four-wheel drive direct-coupling) range until the governor pressure becomes lower than the predetermined value, and the transfer mechanism 10 is changed into the gear position of L<sub>4</sub> range after the governor pressure drops below the predetermined value.

Now, the operations are described in connection with the respective ranges which are selected by the manual valve 105 of the automatic transmission and the manual shift of the transfer mechanism.

(1) Where the manual valve 105 in D-, 2-, L- or R-range position, in which the governor pressure commensurate with vehicle speed is fed to the valve means:

(A) When the manual shift is in H<sub>2</sub> range and the transfer mechanism is in the gear position of H<sub>2</sub> range (two-wheel drive direct-coupling mode),

the 1st solenoid valve 210 is "ON", and

the 2nd solenoid valve 220 is "OFF"

so that the line pressure in conduit 104 which is led to conduit 205 through orifice 340 is drained by the de-energized first solenoid valve 210, without being admitted into the upper oil chamber 236 of the change-over valve 230. Therefore, the spool 231 of the change-over valve 230 is held in the upper position by the spring 232, and the line pressure from conduit 104 is applied to the oil chamber 252 through the oil chamber 234 and fourth conduit 204, holding the second and first spools 242 and 241 of the inhibitor valve 240 in the respective lower positions. Consequently, the line pressure is fed to the hydraulic servomotor 70 of the clutch 7 from the conduit 104 through the oil chamber 250, first conduit 201 and check valve 310, while the oil pressures in the hydraulic servomotors 80 and 50 are drained through the drain ports 238 and 255, respectively. Thus, the transfer mechanism 10 is set in the gear position of H<sub>2</sub> range (two-wheel drive direct-coupling mode).

(B) When the manual shift is in H<sub>4</sub>-range and the transfer mechanism is in the gear position of H<sub>4</sub> range (four-wheel drive direct-coupling mode),

the 1st solenoid valve 210 is "OFF", and

the 2nd solenoid valve 220 is "OFF"

so that the line pressure in the conduit 104 is led to the conduit 205 through orifice 340. However, since the first solenoid valve 210 is in de-energized state, the line pressure is admitted into the upper oil chamber 236 of the change-over valve 230, holding the spool 231 in the lower position. Consequently, the line pressure from the conduit 104 is fed to the hydraulic servomotor 80 of the clutch 8 through the second intermediate oil chamber 235, check valve 330, modulator valve 270 and third conduit 203. On the other had, the line pressure which is also led to the conduit 206 from the conduit 104 through orifice 350 is admitted into the upper oil chamber 253 since the second solenoid valve 220 is in de-energized state, holding the third, second and first spools 243, 242 and 241 of the inhibitor valve 240 in the respective lower positions. Therefore, the line pressure is fed to the hydraulic servomotor 70 of the clutch 7, and the oil pressure in the hydraulic servomotor 50 is drained through the drain port 255. Thus, the transfer mechanism 10 is set in the gear position of H<sub>4</sub> range (four-wheel drive direct-coupling mode).

(C) When the manual shift is in L<sub>4</sub>-range with a vehicle speed higher than a predetermined value, and the transfer mechanism is in the gear position of H<sub>4</sub> range (four-wheel drive direct-coupling mode),

the 1st solenoid valve 210 is "OFF", and

the 2nd solenoid valve 220 is "ON"

so that the line pressure of the conduit 104 which is led into the conduit 205 through orifice 340 prevails in the upper oil chamber 236 since the first solenoid valve 210 is in de-energized state, holding the spool 231 of the change-over valve 230 in the lower position. Accordingly, the line pressure is fed to the hydraulic servomo-

tor 80 of the clutch 8. On the other hand, the line pressure which is also led into the conduit 206 from the conduit 104 through the orifice 350 is drained by the energized second solenoid valve 220, so that it is not admitted into the upper oil chamber 253 of the inhibitor valve 240. Also, the line pressure is not fed into the oil chamber 252 because the spool 231 of the change-over valve 230 is in the lower position. As the governor pressure prevails in the oil chamber 251, the second and third spools 242 and 243 are shifted to the respective upper positions. The governor pressure is in excess of the predetermined level, so that the first spool 241 is held in the lower position shown, overcoming the force of the spring 244. Therefore, the line pressure is fed to the hydraulic servomotor 70 of the clutch 7, and the oil pressure in the hydraulic servomotor 50 is drained through the drain port 255. Thus, the transfer mechanism 10 is set in the gear position of H<sub>4</sub> range (four-wheel drive direct-coupling mode).

(D) When the manual shift is in L<sub>4</sub>-range with a vehicle speed lower than the predetermined value and the transfer mechanism is in the gear position of L<sub>4</sub> range (reduced-speed four-wheel drive mode),

the 1st solenoid valve 210 is "OFF", and

the 2nd solenoid valve 220 is "ON"

so that the line pressure which is led from the conduit 104 into the conduit 205 through orifice 340 is admitted into the upper oil chamber 236 since the first solenoid valve 210 is in de-energized state, setting the spool 231 of the change-over valve 230 in the lower position shown. Consequently, the line pressure is fed into the hydraulic servomotor 80 of the clutch 8. On the other hand, the line pressure which is also led from the conduit 104 to the conduit 206 through orifice 350 is drained by the energized second solenoid valve 220. The line pressure is thus not admitted into the upper oil chamber 253 of the inhibitor valve 240. Also the line pressure is not fed into the oil chamber 252. In this instance, the governor pressure prevails in the oil chamber 251, the second and third spools 242 and 243 are shifted to the respective upper positions, and, since the governor pressure is lower than the predetermined level and overcome by the force of the spring 244, the first spool 241 is held in the upper position, admitting the governor pressure into the lower oil chamber 248 through the oil port 245A in the sleeve. Therefore, the line pressure is fed to the hydraulic servomotor 50 of the multiple disc brake 5 from the conduit 104 through oil chamber 249, second conduit 202 and check valve 320, while the oil pressure in the hydraulic servomotor 70 is drained through the first conduit 201, second intermediate oil chamber 250 and drain port 256, or through the oil chamber 250, intermediate oil chamber 264 of the downshift timing valve 260 and drain ports 266 and 268. Thus, the transfer mechanism is set in the position of L<sub>4</sub> range (reduced-speed four-wheel drive mode).

The upper and lower end faces of the first spool 241 of the inhibitor valve 240, which face respectively the oil chamber 251 and lower oil chamber 248, have the same pressure receiving areas, so that when the spool is shifted to the upper position, admitting the governor pressure into both the oil chamber 251 and the lower oil chamber 248, it will not be shifted to the lower position and held in the upper position by the action of the spring 244 even if the governor pressure (or the vehicle speed) is increased, until the manual shift is set in the H<sub>2</sub>- or H<sub>4</sub>-range position to admit the line pressure into the oil chamber 252 or into the upper oil chamber 253.

Therefore, in a case where the L<sub>4</sub>-range is selected by the manual shift and established the gear position of L<sub>4</sub> range of the transfer mechanism upon a drop of the vehicle speed (or governor pressure) below a predetermined value, that gear position of L<sub>4</sub> range is maintained even after the vehicle speed (or governor pressure) is increased.

(2) Where the manual valve 105 in N- or P-range in which no governor pressure is fed to the valve means:

- (E) When the manual shift selects L<sub>4</sub>-range,  
the 1st solenoid valve 210 is "ON", and  
the 2nd solenoid valve 220 is "ON"

so that the line pressure which is led from the conduit 104 to the conduit 205 through orifice 340 is drained by the energized first solenoid valve 210, supplying no line pressure to the upper oil chamber 236. Therefore, the spool 231 of the change-over valve 230 is held in the upper position by the action of the spring 232, applying the line pressure to the oil chamber 252 of the inhibitor valve 240 from the conduit 104 through the oil chamber 234 and the fourth conduit 204, setting the second and first spools 242 and 241 of the inhibitor valve 240 in the respective lower positions. Consequently, the line pressure is fed to the hydraulic servomotor 70 of the clutch 7, and the oil pressure in the hydraulic servomotors 80 and 50 are drained through the drain ports 238 and 255, respectively. Thus, the transfer mechanism 10 is set in the gear position of H<sub>2</sub> range (two-wheel drive direct-coupling mode).

(F) When the manual shift selects H<sub>2</sub> range, or

- (G) When the manual shift selects H<sub>4</sub> range,  
the 1st solenoid valve 210 is "ON", and  
the 2nd solenoid valve 220 is "OFF"

so that the line pressure is admitted into the upper oil chamber 253 of the inhibitor valve 240 in addition to the conditions in (E). However, the change-over valve 230 and inhibitor valve 240 are operated in the same manner, supplying the line pressure to the hydraulic servomotor 70 of the clutch 7 and draining the hydraulic servomotors 50 and 80 to set the transfer mechanism in the gear position of H<sub>2</sub> range.

With the above-described transfer mechanism, if the range of reduced-speed four-wheel drive mode is selected by the manual shift of the transfer mechanism during a high speed operation of the vehicle in the mode of two-wheel drive direct-coupling mode (H<sub>2</sub>) or four-wheel drive direct-coupling mode (H<sub>4</sub>), the first and second solenoid valves 210 and 220 are put in de-energized state and energized state, respectively, as shown in Table 2. However, during the high speed operation of the vehicle in H<sub>2</sub> or H<sub>4</sub> mode, the second solenoid valve 220 has been in de-energized state with its first spool 241 held in the lower position, so that, even if the oil pressure in the upper oil chamber 253 is drained upon energization of the second solenoid valve 220, the governor pressure in the oil chamber 251 holds the spool 241 continuously in the lower position, overcoming the force of the spring 244 as long as the vehicle speed is higher than the predetermined value. Therefore, the transfer mechanism is maintained in the gear position of H<sub>4</sub> range and not changed into L<sub>4</sub> range until the governor pressure drops below the predetermined level.

However, in a high speed operation of the vehicle where the transfer mechanism is established in H<sub>4</sub> range, if the manual shift of the automatic transmission is set in D-range after once setting the same in N-range in which the feeding of the governor pressure is stopped, the governor pressure which has been prevailing in the oil

chamber 251 of the inhibitor valve 240 is drained at the time when the manual shift is set in the N-range position, as a result shifting the spool 241 to the upper position by the action of the spring 244. As soon as the manual shift is set in the D-range position, the governor pressure is admitted into the oil chamber 251 as well as the lower oil chamber 248 through the oil port 245A in the sleeve-like land to hold the spool 241 in the upper position. In such a case, the transfer mechanism 10 is changed into the gear position of reduced-speed four-wheel drive range L<sub>4</sub>, abruptly changing the mode of operation of the vehicle to reduced speed four-wheel during operation abruptly from a high speed driving operation in H<sub>4</sub> range.

In order to avoid such dangerous situations, the electric control circuit employed by the present invention includes means for supplying the first solenoid valve 210 with a signal indicative of the selection of N- or P-range by the manual shift of the automatic transmission, thereby holding the first solenoid valve 210 in energized state to feed the line pressure to the hydraulic servomotor 70 of the multiple disc clutch 7 irrespective of the mode selected by the manual shift of the transfer mechanism, as will be described in greater detail hereinafter.

FIGS. 7 and 8 illustrate Example 1 and 2, respectively, of the electric circuit which energizes and de-energizes the first and second solenoid valves 210 and 220 as shown in Table 2 according to the selected range selected by the manual selector valve 105 of the automatic transmission and the mode of operation selected by the manual shift of the transfer mechanism 10.

#### EXAMPLE 1

The electric circuit includes an ignition switch 400, a starter motor 410, a battery 420 and a manual shift or a selector switch 500 for the transfer mechanism 10. Indicated at 600 is a neutral safety switch which permits to start the internal combustion engine only in N- and P-ranges of the automatic transmission, and is turned on by the shift lever of the automatic transmission when the N- or P-range is selected thereby, actuating a relay 601 and closing relay contacts 602 and 603 to energize ("ON") the first solenoid valve 210 irrespective of the mode of operation (H<sub>2</sub>-mode, H<sub>4</sub>-mode and L<sub>4</sub>-mode) selected by the selector switch 500.

#### EXAMPLE 2

In this case, the relay 601 and relay contacts 602 and 603 are omitted by the use of a safety switch 600 A for two circuits.

While the present invention has been described in a preferred embodiment thereof, the present embodiment is illustrative and not restrictive and in a modification, a manual speed-selector valve for selectively controlling, through manual operation, the line pressure application to the respective input oil chambers of a selector valve and inhibitor valve (the top oil chamber 236 of the selector valve 230 and the top oil chamber 252 of the inhibitor valve 240, in the embodiment described hereinbefore) may be employed instead of those two solenoid valves 210 and 220.

The operation of the system in shifting from the mode (A), (B) or (C) to the mode (D) will be described hereinafter with reference, mainly, to the operation of the inhibitor valve 240 and the down-shift timing valve 260.

When the mode (A) or (B) is shifted to mode (C), namely, when the transfer mechanism is shifted from

the H<sub>2</sub> range or the H<sub>4</sub> range to the L<sub>4</sub> range while the vehicle is running at a running speed below a given running speed, and when the mode (C) is shifted to the mode (D), namely, when the transfer mechanism is shifted manually to the L<sub>4</sub> range and the running speed of the vehicle, which has been running at a running speed above the given running speed with the transfer mechanism in H<sub>4</sub> range, is reduced to a running speed below the given running speed, the first spool 241 of the inhibitor valve 240 is moved to the upper position due to the operation of the first and second solenoid valves 210 and 220 and/or the reduction in the governor pressure. Consequently, the hydraulic servomotor 70 is drained through the first conduit 201, the second middle oil chamber 250, the fifth conduit 207, the middle oil chamber 264 and the drain ports 266 and 268 so that the direct-coupling multiple disk clutch 7 is disengaged and at the same time, the line pressure is applied to the hydraulic servomotor 50 and to the bottom oil chamber 262 of the down-shift timing valve 260 through the conduits 104, first middle oil chamber 249 and the second conduit 202 provided with a check valve 320 therein so that the reduced-speed drive multiple disk brake 5 is engaged and the spool 261 of the timing valve 260 is moved to the upper position.

In the operation as described hereinbefore,

(1) When the line pressure is lower than a predetermined level (small throttle opening);

Since a low line pressure is applied to the top oil chamber 265 of the timing valve 260 through the conduit 104, the spool 261 is moved to the upper position by the spring 262 allowing the fifth conduit 207 for draining the hydraulic servomotor 70 communicate with the first and second drain ports 266 and 268 so that the hydraulic servomotor 70 is drained quickly. Accordingly, the oil pressure  $a_1$  in the hydraulic servomotor 50 and the oil pressure  $b_1$  in the hydraulic servomotor 70 vary with time as shown in FIG. 5.

(2) The line pressure is higher than the predetermined level (large throttle opening);

Since a high line pressure is applied to the top oil chamber 265 of the timing valve through the conduit 104, the spool 261 is moved to the lower position against the force of the spring 262. In the initial stage, the hydraulic servomotor 70 is drained gradually only through the drain port 266 provided with the orifice 267. When the pressure for engaging the multiple disk brake 5 is applied to the bottom oil chamber 263 through the conduit 202, the hydraulic pressure working in the top oil chamber 265 is balanced with the hydraulic pressure working in the bottom oil chamber 263. Consequently, the spool 261 is moved to the upper position by the spring 262 so that the fifth conduit 207 is allowed to communicate with, in addition to the first drain port 266 provided with the orifice 267, the second drain port 268 so that the hydraulic servomotor 70 is drained quickly. Accordingly, the oil pressure  $a_2$  in the hydraulic servomotor 50 and the oil pressure  $b_2$  in the hydraulic servomotor 70 vary with time as shown in FIG. 6.

As described hereinbefore, since the shift timing in shifting the transfer mechanism from the H<sub>2</sub> or H<sub>4</sub> range to the L<sub>4</sub> range is controlled when the throttle opening is small (for example, while running along a level road) so that the reduced-speed drive brake 5 is engaged after the direct drive clutch 7 has been disengaged, shocks resulting from the shifting operation can favorably be reduced. On the other hand, since the operation of en-

gaging the reduced-speed drive brake 5 overlaps with the operation of disengaging the direct-coupling clutch 7 when the throttle opening is large (for example, when the transfer mechanism is shifted from the H<sub>4</sub> range to the L<sub>4</sub> range while running up a steep slope to provide a greater driving force), the transfer mechanism is shifted without becoming neutral state, which ensures safe running.

The function of the modulator valve 270 will be described hereinafter.

When the vehicle is running with the transfer mechanism shifted into H<sub>4</sub> range (four-wheel direct-coupling drive range) by shifting the manual shift lever to the H<sub>4</sub> position (or L<sub>4</sub> position), namely, in the (B) or (C) mode, the right oil chamber 273 of the modulator valve 270 is drained and the third conduit 203 intersecting the middle oil chamber 274 is choked with the spool 271, the position of which is dependent on the balance between the force of the spring 272 and the hydraulic force working in the left oil chamber 275. Consequently, the engaging pressure applied to the hydraulic servomotor 80 is reduced and the torque capacity of the four-wheel drive clutch 8 thereby is reduced, therefore, the clutch 8 slips to absorb a torsion when the torsional stress resulting from the differential revolving rate between the front and rear wheels exceeds the torque capacity of the clutch 8.

When the manual shift lever is adjusted to the L<sub>4</sub> position and the vehicle is running with the transfer mechanism shifted into the L<sub>4</sub> range (reduced-speed four-wheel drive range), namely, when in the (D) mode, the engaging pressure of the reduced-speed drive brake 5 (the level of the line pressure) is applied to the right oil chamber 273 of the modulator valve 270 and the spool 271 is moved to the left position by the spring 272 to open fully the third conduit 203 intersecting the middle oil chamber 274 so that the engaging pressure in the level of the line pressure is applied to the hydraulic servomotor 80 to provide an increased torque capacity for the four-wheel drive clutch 8. Consequently, sufficient four-wheel driving force is provided.

As described hereinbefore, the hydraulic control system of the present invention for a four-wheel drive transfer mechanism, which is connected to the rear end of an automatic transmission and is capable of being shifted between the two-wheel drive direct-coupling range, four-wheel drive direct-coupling range and reduced-speed four-wheel drive range through the functions of direct-coupling frictional engagement means, reduced-speed drive frictional engagement means and four-wheel drive frictional engagement means, comprises means to control the four-wheel drive transfer mechanism in shifting down the four-wheel drive transfer mechanism from the direct-coupling range into the reduced-speed drive range in a manner wherein the disengaging operation of the direct-coupling frictional engagement means overlaps with the engaging operation of the reduced-speed drive frictional engagement means when the throttle opening is greater than a predetermined value, whereas the reduced-speed drive frictional engagement means is engaged after the direct-coupling frictional engagement means has been disengaged when the throttle opening is smaller than the predetermined value. Accordingly, since the reduced-speed drive frictional engagement means is engaged after the direct-coupling frictional engagement means has been disengaged when the throttle opening is small, the shifting shock is reduced and on the other hand, the

disengaging operation of the direct-coupling frictional engagement means overlaps with the engaging operation of the reduced-speed drive frictional engagement means when the throttle opening is large to eliminate neutral state from the down-shift operation when the vehicle is running up a steep slope so that safe running is secured. Thus the hydraulic control system is capable of controlling the down-shift timing of the four-wheel drive transfer mechanism according to the running condition of the vehicle.

What is claimed is:

1. In a hydraulic control system for four-wheel drive transfer mechanism for vehicles, having a two-wheel drive direct-coupling speed range, a four-wheel drive direct-coupling speed range and a reduced-speed four-wheel drive speed range, the improvement comprising:  
 an internal combustion engine;  
 an automatic transmission connected to the output end of said engine;  
 a transfer mechanism comprising a reduction gear mechanism having an input shaft connected to the output end of said transmission, a first output shaft connected to the output end of said reduction gear mechanism, a second output shaft connected so as to be engaged with said first output shaft through a linkage and first frictional engagement means for shifting said transfer mechanism into a four-wheel drive range; second frictional engagement means for connecting the input shaft of said reduction gear mechanism and said first output shaft for shifting said reduction gear mechanism into a direct-coupling drive range, and third frictional engagement means for shifting said reduction gear mechanism into a reduced-speed drive range; and  
 a hydraulic control circuit comprising a hydraulic fluid source for supplying a pressurized fluid of a line pressure having a pressure component commensurate with the throttle opening of said engine; means for generating pressure signals corresponding to said drive range of the transfer mechanism, by operating manual shift means for said transfer mechanism; a first control valve means for selectively supplying said pressurized fluid to a hydraulic servomotor of said first frictional engagement means upon reception of a first pressure signal corresponding to the four-wheel drive range of said transfer mechanism, a second control valve means for selectively supplying said pressurized fluid to a servomotor of said second frictional engagement means, draining a servomotor of said third frictional engagement means upon receipt of a second pressure signal corresponding to the direct-coupling drive range of said reduction gear mechanism, selectively supplying said pressurized fluid to the servomotor of said third frictional engagement means, and draining the servomotor of said frictional engagement means upon reception of a third pressure signal corresponding to said reduction-speed drive range; and a third control valve means for controlling the area of a drain port communicating with the servomotor of said second frictional engagement means through a drain passage upon reception of said pressurized fluid of the line pressure; whereby said third control valve means provides a larger port area for said drain passage when said third pressure signal is applied to said second control valve means and said line pressure is lower than a predetermined level and

whereas said third control valve means provides a smaller port area for said drain passage when said third pressure signal is applied to said second control valve means and said line pressure is higher than said predetermined level.

2. A hydraulic control system according to claim 1, wherein said third control valve means comprises a first pressure chamber for receiving the pressurized fluid of said line pressure, a second pressure chamber communicating with the servomotor of said third frictional engagement means, a spool receiving on opposite ends thereof the respective pressure working within said first and second pressure chambers for movement to control the area of said drain passage and a spring disposed within said second pressure chamber, whereby said spool is controlled so as to provide a larger port area for the drain passage when the line pressure is lower than said predetermined level and to provide a smaller port area for the drain passage when said line pressure is higher than said predetermined level.

3. A hydraulic control system according to claim 1, wherein said third control valve means includes a first drain port and a second drain port communicating with said drain passage and adapted to drain the servomotor of said second frictional engagement wherein means, said third control valve means opens said first drain port and closes said second drain port when said line pressure is higher than said predetermined level, and said third control valve means opens both said first and second drain ports when said line pressure is lower than said predetermined level.

4. A hydraulic control system according to claim 1, wherein said third control valve means includes a first pressure chamber receiving the pressurized fluid of said line pressure, a second pressure chamber communicating with the servomotor of said third frictional engagement means, a spool receiving on opposite ends thereof the respective pressures working within said first and second pressure chambers for movement, a spring disposed within said second pressure chamber and a first and second drain ports communicating with said drain passage and adapted to drain the servomotor of said second frictional engagement means, said spool is moved by the resilient force of said spring to a position where said spool opens said first and second drain ports when said line pressure is lower than said predetermined level, said spool is moved against the resilient force of said spring to a position where said spool keeps said second drain port closed while the pressure prevailing within the servomotor of said first frictional engagement means is lower than a predetermined level when the line pressure is higher than said predetermined level and said spool is moved to a position where said spool is moved to open said first and second drain as ports while the pressure prevailing within said servomotor of said first frictional engagement means is higher than said predetermined level when the line pressure is higher than said predetermined level.

5. A hydraulic control system according to, claims 1, 2, 3 or 4 wherein said system includes further means to generate a speed signal having a pressure component commensurate with the running speed of the vehicle, said second control valve means is an inhibitor valve including at least one spool movably controlled by said second pressure signal and said third pressure signal applied to one end thereof and said speed signal and the resilient force of a spring applied to the other end thereof and adapted to be positioned so that the pressur-

ized fluid is supplied to the servomotor of said third frictional engagement means and the servomotor of said second frictional engagement means is drained when said third pressure signal is applied to said one end of said spool and to be positioned so that the pressurized fluid is supplied to the servomotor of said second frictional engagement means and the servomotor of said third frictional engagement means is drained when said second pressure signal is applied to said one end of said

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spool, said first control valve means is a selector valve including a spool movably controlled by said first pressure signal applied to one end thereof and the resilient force of a spring applied to the other end thereof and adapted to be positioned so that the pressurized fluid is supplied to the servomotor of said first frictional engagement means when said first pressure signal is applied to said one end of said spool.

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